Report for 2002NY1B: Evaluation of Vegetated Filter Areas for Phosphorus Removal

There are no reported publications resulting from this project.

Report Follows:

Problem & Research Objectives:

Phosphorus (P) has been identified as a limiting nutrient in several New York watersheds. In order to achieve the goals of reducing P nutrient inputs to watersheds, various programs and practices are being implemented. Best management practices (BMP's) are often recommended as site-specific measures for reducing contaminant loadings. However, many BMP's are generically adopted based on research conducted in other regions of the United States. For example, vegetated filter strips (VFS) or buffer areas is a BMP that is often recommended. This practice, however, has typically only been shown to be effective in broad, flat landscape settings where soils are deep and runoff moves primarily as sheet flow. In a humid area such as NY, where rainfall is often of long duration at low intensity and where most soils are sloping, shallow or have restricting layers, the effectiveness of VFS is less well understood. Since P can be also transported in dissolved form, the fate of dissolved P through a VFS is perhaps more important. The effectiveness of VFS in removing dissolved P has been controversial, and is not well understood in a New York setting.

The proposed effort will entail a critical review of the literature and the setting from which results are reported, in conjunction with some research in vegetated filter areas. The work will focus on agricultural systems and settings. Specific objectives will be to: 1) Review existing literature regarding dissolved P in VFS, 2) Conduct measurements of dissolved P through vegetated filter areas, and 3) summarize findings incorporating guidelines for improved decision making regarding the use and implementation of vegetated filters for dissolved P nutrient attenuation.

Methodology:

Project Objective 1: Research conducted on laboratory scale or microcosm plot settings of vegetated filters will be reviewed to assess critical variable influences or physical based relationships, but the emphasis will be to find studies on larger scale stream or watershed investigations.

Project Objective 2: The work proposed for Objective 2 will extend current efforts to understand P behavior in soils and in milkhouse grass vegetated filter strips (Murray, 2001). The proposed research will occur on the hillslope scale, with particular emphasis on the near-stream environment. The soil P content will be analyzed for three soil depths (0-5, 5-10, and 10-25 cm) using Morgan's (0.72 M sodium acetate) extraction. Since the project duration is limited to one year, the measured data will be characterized to the season's hydrology and analyzed in accordance with variable constructs based on the review in Objective 1 to determine how well observations fit previously reported results.

Project Objective 3: The findings of Objective 1 and the observations during Objective 2 will be synthesized and summarized into a report structured to facilitate further decision making regarding the use of vegetated filters as a BMP.

Principal Findings & Significance:

We reviewed numerous publications on vegetated filters or buffer areas yet there still seems to be a large gap in understanding of the associated complex biogeochemical cycling of phosphorus (P). There is a growing body of evidence on the mechanisms controlling P transformations but few data addressing the rates and limits of these processes. These gaps in the knowledge base limit the ability to model, or better evaluate experimentally P-cycling in the landscape. We found numerous examples of different terminology in the literature (i.e., field borders, contour grass strips, grassed waterways, grassed hedges, vegetative barrier, vegetative screen, filter strips, shelter belts, non-disturbance area, riparian buffer zone, infiltration galley, and wetland) which simultaneously confuse buffer discussions and add some clarification on the form of P to be controlled and the mechanisms based on the landscape position. In general, vegetated filters are quite effective in the physical processes of deposition and filtration, removing particulate P (PP) or organically bound P as long as there is shallow, uniform flow across the area. Suggested filter widths vary from a few meters to several hundred meters usually based on the land slope, vegetation type, and particle grain size. However, vegetated filters serving as a sink for particulate forms of P, are often reported as a source of dissolved P (DP) or bioavailable P following biological and chemical transformations and subsequent hydrological events (Uusi-Kamppa *et al.*, 1996; Correl, 1999; NRC, 2002). Unsaturated upland vegetated filter areas, where infiltration can occur into soils high in organic matter, aluminum and iron oxides, and calcium, can be effective at removing both PP and DP. Infiltration into sandy or peat soils which have little potential for adsorption and precipitation of DP are not truly effective P sinks, although several articles claim a 100% P removal because all the surface water was infiltrated. Vegetated filters in areas with fluctuating degrees of saturation, even those containing DP adsorptive soils, often release P upon wetting as a result of anaerobic or reducing P transformations. Areas where saturation conditions prevail, such as riparian buffers along gaining streams and wetlands, were often reported to be effective at trapping PP, only to release it later as DP. As a result, the benefits of implementing vegetated filter areas to remove P vary widely. We found a range of –114 to 100 percent reductions in P concentration for the variety of vegetated filters described in the literature. Overall, the retention of DP is much less efficient and more difficult to achieve compared to PP, and in some cases, losses of DP were increased.

We found in the literature that P assimilation by vegetation is temporal and appears to have little long-term effect in P removal. Although rapidly growing plants may uptake as much as 40 kg P/ha/yr, most of this is recycled to the vegetative filter strip in decaying plant residue. Several authors claim that biomass harvesting and removal was not a very significant P removal mechanism compared to the P loading used. Rapidly growing willows, sweetgum and red maple trees can take up about 10 kg P/ha/yr, but approximately 8.3 kg P/ha/yr is returned as leaf litter and throughfall (Adegbidi *et al.*, 2001; Peterjohn and Correll, 1984). Consequently, forest vegetated areas may only have minimal long-term removal amounts during growth. The microbiological activity of the soil can also utilize and extract P, but again most of this is recycled within a vegetated filter area during the endogenous stage. A large body of literature reports on the effectiveness of trapping eroded materials and sediments (i.e., PP) with different types of plants, and some models have been developed for this purpose (Inamdar *et al.*, 1999; Munoz-Carpena and Parsons, 2000). However, several of these same studies acknowledge that there are physical limits to the amount of deposition, and that usually sediment bound P is eventually re-entrained or bio-chemically transformed into DP that can be transported in subsequent hydrological events. Concentrated flows limit deposition of PP or find new paths through previous depositional areas reducing the effect of vegetated filters. Concentrated flows are prevalent in humid and high-topographic relief areas such as the Northeast.

Vegetated filter areas that can effectively reduce DP concentrations will be an important component to reducing surface water quality impairments attributed to excessive P loading.

Surface runoff from agricultural and urban nonpoint areas can contain from 10 to 45% P in the DP form (Pietilainen and Rekolainen, 1991; Cowen and Lee, 1976; Scott *et al.*, 1998). Point sources such as milk house, barnyard runoff, pulp/paper mill wastewater, and secondary treated municipal wastewater can contain from 65 to 85% of the total P as DP (Schwer and Clausen, 1989; Schellinger and Clausen, 1992; Priha, 1994).

We hypothesized that vegetative filters are less effective at reducing DP when preferential flows occur or under wet and fluctuating soil saturation conditions. We carried out experiments in a vegetated filter area receiving milk house wastewater and also in a natural vegetated riparian buffer between a manured cornfield and a stream. We found that preferential or concentrated flow paths occurred in both these settings, despite the installation of a level-lip spreader board to diffuse the flow in the milk house vegetated filter. The milk house vegetated filter was generally unsaturated, and soil tests revealed that the soil had sufficient capacity to adsorb P based on the presence of aluminum and iron oxides. Where the wastewater flow infiltrated, the DP concentration was reduced from an average of 9.1 to 0.8 mg/l over a distance of 36m. Wastewater that flowed over the surface had DP concentrations ranging from 13.7 to 5.9 mg/l over the same 36m. The milk house wastewater that was applied had an initial average concentration of 15.8 mg/l of DP. For this case, the reduction in DP concentration was best fitted to an exponential decay function (Geohring *et al.*, 2003). In the natural vegetated riparian buffer, the DP concentration was reduced from an average of 0.11 (at edge of manured corn field) to 0.07 mg/l (next to the stream) over a 38m distance, when the flow was primarily subsurface. However, during a wet period, the DP concentration went from 0.72 to 0.15 mg/l across the 38m distance. The wet period produced some concentrated flow and raised the water table in the natural buffer, ultimately increasing the concentration immediately adjacent to the stream. The estimated shallow lateral flow DP loading to the stream in this situation, based on the soils hydraulic conductivity in the riparian area, is 0.008 g/d per square meter streambed interface. In both experiments, the explicit hydrology influenced the observed DP concentrations and potential transport rates.

The literature review and experimental findings suggest that in order for vegetated filters to effectively reduce DP, they need to be placed in an unsaturated part of the landscape and consist of soil which can geochemically adsorb and fix P. The water needs to be introduced to these areas such that it is distributed uniformly, and minimizes soil saturation and surface runoff. Any preferential flow through the profile, or concentrated flow across the surface reduces the residence time required for the kinetic biochemical adsorption reactions. Vegetated filters or riparian areas located next to gaining streams for the purpose of trapping PP, may put P enriched sediments in a high risk location because the rising water table creates anaerobic conditions which can transform P to soluble forms.

Notable Achievements:

The results of this work have generated considerable interest on behalf of conservationists, engineers, and practitioners interested in the design and application of vegetated filter strips to control point and nonpoint sources of pollution in agricultural settings. We've been invited to present findings at the East Regional (includes Northeast and Mid-Atlantic states) USDA-NRCS Technical Workshop, and a presentation was delivered to the NY-NRCS Training program. Fifty people have signed up for a Filter Areas session at the NYS S&WCC 2003 Water Quality Symposium.

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